Turk J Bot
24 (2000) 13–24

Research Article

Weekly Variations in Phytoplankton Structure of a Harbour in Mersin Bay (north-eastern Mediterranean)

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Received: 14.07.1998
Accepted: 29.07.1999

Abstract: Weekly variations in the phytoplankton composition of a harbour in Mersin Bay were studied with two methods: filtration for the assessment of >55 µm phytoplankton from July 1995 to June 1997; and sedimentation for the assessment of all phytoplankton (both>55 µm and <55 µm) between 15 February and 25 May in 1996. With both sampling methods, a total of 175 phytoplankton species were identified. In the filtered samples, the total diatom abundance was much higher than that of dinoflagellates. The highest diatom abundance was detected on 8 February 1996 ($11.7x10^3$ cells 1^{-1}) and 19 June 1997 ($11.1x10^3$ cells 1^{-1}), represent mainly by the species *Asterionella japonica* Cleve and *Rhizosolenia alata* Brightwell respectively. The highest dinoflagellate abundance (737 cell 1^{-1}) in the filtered samples occurred on 4 April 1996. However, on the following day a dinoflagellate (*Prorocentrum micans* Ehrenberg) bloom was found in great numbers ($90.9x10^6$ cells 1^{-1}) in the sedimented samples. When this number was compared with the *P. micans* abundance of the previous day ($3.1x10^6$ cell 1^{-1}) in the sedimented samples, the growth rate of this species was calculated as ~3.37 day^{-1}. In this study, two techniques of phytoplanton analysis (sedimentation and filtration through a 55 µm mesh) were compared, the advantages and disadvantages of both methods wete assessed, and it was concluded that both techniques should be applied during the process of phytoplankton enumeration. The contribution of small forms, mostly coccolithophorids and small flagellates (<20 µm), to the total phytoplankton abundance was found to be 37±21%.

Key Words: Phytoplankton composition, Mediterranean, size groups, nanoplankton

Mersin Körfezindeki (Kuzey-doğu Akdeniz) bir Limanın Fitoplankton Topluluk Yapısındaki Haftalık Değişimler

Özet: Mersin Körfezindeki bir limanın fitoplankton kompozisyonundaki haftalık değişimler iki metod kullanılarak çalışıldı; filtrasyon >55 µm fitoplanktonların değerlendirilmesinde Temmuz 1995'den Haziran 1997'ye kadar; sedimentasyon tüm fitoplankterlerin (her iki >55 µm ve <55 µm) değerlendirilmesinde, 15 Şubat ve 25 Mayıs 1996 tarihleri arasında. Her iki örnekleme metodu sonucunda toplam 175 fitoplankton türü tanımlandı. Filtre edilmiş örneklerde toplam diatom bolluğu dinoflagellatlarınkinden daha fazlaydı. En yüksek diatom bollukları 8 Şubat 1996 ($11.7x10^3$ hücre 1^{-1}) ve 19 Haziran 1997 ($11.1x10^3$ hücre 1^{-1}) tarihlerinde bulundu ki diatomlar bu dönemlerde sırasıyla *Asterionella japonica* Cleve ve *Rhizosolenia alata* Brightwell tarafından ağırlıklı olarak temsil edildi. Filtre edilmiş örneklerde en yüksek dinoflagellate bolluğu (737 hücre 1^{-1}) 4 Nisan 1996'da ortaya çıktı. Bununla birlikte, ertesi gün dinoflagellate türü (*Prorocentrum micans* Ehrenberg) bolluğunun çöktürülmüş örneklerde muazzam rakamlara ($90.9x10^6$ hücre 1^{-1}) ulaştığı farkedildi. Bu rakam bir önceki günün çöktürülmüş örneklerindeki *P. micans* bolluğuyla karşılaştırıldığında bu türün büyüme oranı ~3.37 gün^{-1} olarak tespit edildi. Bu çalışmada, fitoplankton analizinin iki tekniği (çöktürme ve örneklerin 55 µm'luk bir ağdan filtre edilmesi) karşılaştırıldı, avantajları ve dezavantajları değerlendirildi ve fitoplankton sayma işlemi esnasında iki tekniğin de kullanılması gerektiği doğrulandı. Küçük formların, çoğunlukla kokolitoforidler ve küçük flagellatların (<20 µm) toplam fitoplankton bolluğuna olan katkısı %37±21 olarak bulundu.

Anahtar Sözcükler: Fitoplankton kompozisyonu, Akdeniz, boy grupları, nanoplankton

Introduction

Although several studies have been done on primary production and Chlorophyll-a (1, 2, 3), the phytoplankton composition of the eastern Mediterranean Sea has not been well studied (4, 5, 6). In the present study, during a two-year period, weekly variations in the phytoplankton (>55 µm) composition were observed. In addition to this, for a three-month period (from 15 February to 25 May 1996), the share of smaller-sized phytoplankton (<55 µm) was also assessed. Changes in abundance, species number and temperature were noted and compared with the results of other investigations.

Material and methods

In this study, phytoplankton composition in the harbour (36°31'N 34°19'E) of the Institute of Marine Sciences (IMS) of Middle East Technical University (METU), Erdemli in Mersin Bay was studied at weekly intervals with two different methods: filtration and sedimentation. The location of harbour is shown in Fig. 1. All samples were consistently taken from the surface of its eastern pier at 08:30 a.m. every Thursday.

For the filtration method, samples were collected weekly between 7 July 1995 and 26 June 1997 (≡ filtered samples, a total of 105 samples). The 20-litre seawater samples were filtered through 55 µm mesh. The filtrates were gently washed with 4% buffered formaldehyde into dark bottles. Whole filtrates were directly counted within a graduated petri dish, since the abundance of cells was usually low. When the number of cells was high, subsampling was performed.

For the sedimentation method, one-litre seawater samples were collected (without filtering) again at weekly intervals between 15 February and 25 May 1996 (≡ sedimented samples, a total of 14 samples) for assessment of phytoplankton of both <55 µm and >55 µm. In this method, the whole sample was sedimented without filtration for the counting process. After sedimentation, the phytoplankton were enumerated by a Sedgewick Rafter cell.

A Nikon TMS inverted, phase contrast light microscope was used for species determinations of phytoplankton. References used for the identification of phytoplankton species were Fritsch (7), Cupp (9), Proshkina-Lavienko (9), Kiselev (10), Massuti & Margalef (11), Rampi & Bernhard (12, 13), Round et al. (14), Palmer (15), Schmidt et al. (16) and Smith (17).

During sampling, the only environmental parameter measured was sea surface temperature. Phytoplankton diversity values were calculated according to the Shannon-Weaver diversity index (1948, in: Zar, 18):

$$H' = -\sum_{i=1}^{k} p_i \log_2 p_i$$

Here, k is the number of categories (i.e., the number of phytoplankton species) and p_i is the proportion of the observations found in category i (i.e., proportion of abundance of "i" th species to total abundance).

In the calculation of confidence limits (±) standard error of values were multiplied by $t_{0.05(2)}$. It can be stated concisely as

$$\bar{X} \pm t_{\alpha(2),\,v} S_{\bar{x}}$$

Here "$\bar{X}$" is the average of a vaule (i.e., average of phytoplankton abundance), $t_{\alpha(2),\,v}$ is the critical value of t for a two-sided test for the degrees of freedom "v", and $s_{\bar{x}}$ is the standard deviation of mean or standard error which is equal to $S/\sqrt{n}$ where "s" is the standard deviation and "n" is the sample size (Zar, 18).

Results and Discussion

Species composition and diversity

In this study, a total of 175 phytoplankton species (102 diatoms, 66 dinoflagellates, 1 silicoflagellate, 1 euglenoid, 1 chlorophyte, 2 cyanophytes, and 2 prymnesiophytes) were identified in both methods (Table 1). This number is higher than that found in previous studies for this region. Kıdeyş et al. (6) detected 111

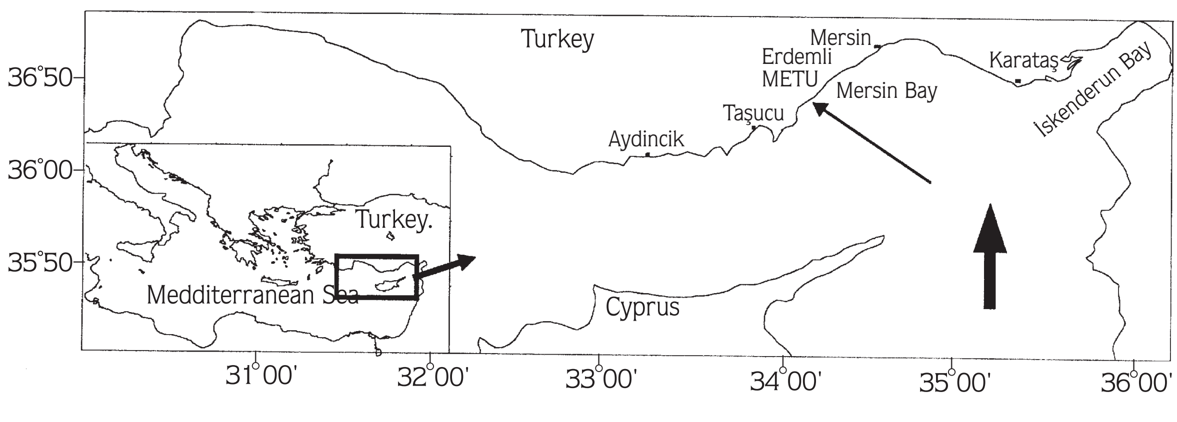

Figure 1. Sampling location.

phytoplankton species (62 diatoms, 47 dinoflagellate and 2 silicoflagellate species) in their monthly net sampling (55 µm mesh) off Erdemli between November 1984 and October 1985. In Polat's study, (19), a total of 159 phytoplankton species (>55 µm), comprised of 83 diatoms, 73 dinoflagellates, 1 cyanophyte, 1 silicoflagellate and 1 prymnesiophyte, were identified between September 1994 and October 1995 in Iskenderun Bay. El-Maghraby & Halim (4) detected 62 dinoflagellates and 57 diatoms in Alexandria waters between December 1956 and July 1957 by the sedimentation method. In the present study, the maximum number of species (43 sp.) was found on 4 April 1996, whilst the minimum number (9 sp.) was recorded 24 August 1995 (Fig. 2).

Table 1. Occurrence of phytoplankton species in different months. Data are related both to filtration (f) (July 1995 and 1997) and sedimentation (s) methods (February and May 1996).

	1995						1996												1997					
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
CYANOPHYCEAE **(Cyanophytes)**																								
Merismopedia cf. punctata Meyen			f																					
Spirulina cf. *princeps* W. et G.S. West																			f	f				
DINOPHYCEAE **(dinoflagellates)**																								
Ceratium arietinum Cleve										f														
Ceratium breve Schmidt										f														
Ceratium candelabrum (Ehrenberg) Stein	f	f							f	f	f		f				f					f	f	f
Ceratium carriense Gourret		f			f		f		f		f		f				f							
Ceratium contortum var. *karsteni* (Pavillard) Sournia		f	f		f				f	f		f				f								
Ceratium contortum var. *robustum* (Karsten) Sourina					f																			
Ceratium compressum Gran			f																					
Ceratium declinatum (Karsten) Jörgensen	f	f							f	f	f						f					f	f	
Ceratium biceps Claparede et Lachmann																						f	f	f
Ceratium furca (Ehrenber) Claparede et Lachmann	f		f						f		s	f	f										f	f
Ceratium fusus (Ehrenberg) Dujardun	f	f	f			f	f		f	f	f	f	f	f	f				f			f	f	
Ceratium gibberum Gourret		f	f			f		f	f	f	f		f						f			f	f	
Ceratium hexacanthum Gourret			f	f				f		f	f									f		f		
Ceratium cf. *horridum* (Cleve) Gran	f																							
Ceratium kofoidi Jörgensen				f									f											
Ceratium macroceros (Ehrenberg) Vanhöffen													f	f	f	f			f	f	f	f	f	f
Ceratium massiliense (Gourret) Jörgensen																	f		f	f	f	f	f	f
Ceratium setaceum Jörgensen		f		f			f				f	f	f	f					f			f		
Ceratium symmetricum Pavillard															f	f	f		f	f	f	f	f	
Ceratium tripos (O.F. Müller) Nitzsch														f			f	f	f	f		f	f	f
Ceratium trichoceros (Ehrenberg) Kofoid													f	f	f	f							f	f
Ceratocorys horrida Stein													f	f	f		f					f	f	f
Dinophysis acuta Ehrenberg													f											
Dinophysis caudata Saville-Kent											f								f		f		f	f
Dinophysis dens Pavillard	f									f	f	f	f	f			f							
Dinophysis diegensis Kofoid																					f			
Dinophysis tripos Gourret																						f		

Table 1 Continue

	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
Dinophysis sp.											f													
Diplopsalis cf. *lenticula* Bergh										f		f							f					
Gonyaulax diegensis Kofoid										f														
Gonyaulax digitale (Pouchet) Kofoid											s													
Gonlaumax monocantha Pavillard										f	f													
Gonyaulax polygramma Stein										f	f													
Gonyaulax turbynei Murrey et Whitting										f														
Gonyaulax sp.										f	f													
Gymnodiriuk sanguineum Hirasaka											s													
Gymnoddinium sp.										f														
Gyrodinium fusiformis Kofoid et Swezy											s													
Gyrodinium lachryma Meunier										f	b													f
Gyrodinium sp.											f													
Heterodinium cf. *milneri* Murrey et Whitting										f														
Ornithocecus quadratus Schütt	f											f												
Ornithocercus sp.											f		f											
Pavillardinium splendidum (Rampi) Rampi											f													
Prorocentrum cordata (Ostenfeld)									s	f	s													
Protoperidinium brochi (Kofoid) et Swezy) Balech													f				f						f	
Protoperidnium claudicans (Paulsen) Balech																			f	f	f	f	f	
Protoperidinium crassipes (Kofoid) Balech			f	f					f			f		f			f	f				f		
Protoperidinium depressum (Bailey) Balech	f							f	f		f		f	f	f	f	f		f				f	f
Protoperidinium cf. *divergens* (Ehrenberg) Balech	f	f	f						f		f		f		f	f	f	f	f				f	f
Protoperidinium globulus (Stein) Balech									f	f	f		f	f		f						f		
Protoperidinium cf. *grande* (Kofoid) Balech											f													
Protoperidinium granii (Ostenfeld in Paulsen) Balech	f									b	f		f						f				f	
Protoperidinium leonis (Pavillard) Balech								f	s	f					f	f				f	f			
Protoperidinium murrayi (Kofoid) Balech	f			f				f	f	f					f									
Protoperidinium oblongum (Aurivillius) Parke et Dodge	f																	f					f	
Protoperidinium oceanicum (Vanhöffen) Balech	f	f									b		f		f				f				f	
Peridinium oviforme (Dangeard) Balech				f						f	f	f	f	f	f	f	f							
Protoperedinium cf. *pedunculatum* (Schütt) Balech											b			f			f							
Protoperidinium pellucidum Balech				f																			f	
Protoheridinium cf. *pentagonum*	f												f										f	
Protoperidinium quarnerense (Schröder) Balech	f			f							f		f	f	f									
Protoperidinium solidicorne (Mangin) Balech											f									f			f	

Table 1 Continue

	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
Protoperidinium steinii (Jörgsen) Balech	f							f	f	f	s													
Protoperidinium triochoideum (Stein) Baelch									s	s														
Protoperidinium sp.											f	f	f				f						f	
Polykrikos schwarzii Bütschlii																						f		
Prorocentrum micans Ehrenberg									b	b	b													f
Pyrophagus horologium Stein	f	f							f	f	f	f	f	f		f								
Pyrophacus steini (J. Schiller) Wall et Dale	f	f																						
Pyrophacus sp.			f										f										f	f
PRYMNESIOPHYCEAE																								
Halasphaera cf. *viridis* Schmitz									f							f								
(Coccolithophores)																								
Emiliania huxleyii (Lohman) Hay et Möller								s	s	s	s													
Syracosphaera sp.																								
DICTYOCHOPHYCEAE																								
(Silicoflagellates)																								
Dictyocha fibula Ehrenberg					f	f	f	f											f					
BACILLARIOPHYCEAE																								
(Diatoms)																								
Achnantes brevipes Agardh												f												
Achnanthes longipes Agardh				f			f	f	f	b	b		f			f		f	f	f	f	f	f	
Amphora ovalis Kützing				f																				
Amphiprora cf. *paludosa W. Smith*			f						f					f										
Asterionella japonica Cleve	f	f		f	f	f	f	b	f	b	f	f	f	f	f	f	f	f	f	f	f	f	f	
Asterolampra japonica (Wallich) Greville															f									
Bacillaria paradoxa Gmelin	f	f	f	f	f	f	f	f	f	f		f	f	f	f	f	f	f	f	f	f	f	f	f
Bacteriastrum cosmosum Pavillard				f																				
Bacteriastrum delicatulum Cleve		f			f					f	f			f	f	f	f					f		
Bacteriastrum elegans Pavillard	f	f			f	f				f	s		f		f		f							
Bacteriastrum elongatum Cleve	f														f									
Bacteriastrum mediterraneum Pavillard				f			f																	
Bacteriastrum sp.							f	f			f	f		f		f	f			f		f		
Biddulphia alternans (Bailey) Van Heurck		f																	f					
Biddulphia pellucida Castrac	f				f					f	f	f	f							f	f	f		f
Biddulphia pulchella Gray		f	f	f	f	f	f	f	f	f				f	f	f		f	f	f	f		f	f
Biddulphia regia (M. Schultze) Ostenfeld	f	f	f	f	f	f	f						f		f	f		f	f	f	f	f		
Camphylodiscus decorus Brehisson												f	f											
Chaetoceros affinis Lauder	f			f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f
Chaetoceros anastomosans Grunow in Van Heurck										f	f													
Chaetoceros cf. *breve* Schütt	f				f	f																		
Chaetoceros constrictum Gran	f							f	f															
Chaetoceros compressum Lauder						f											f							
Chaetoceros cf. *costatum* Pavillard						f	f	f									f							
Chaetoceros crinitus Schütt						f	f	f		f	f		f	f			f						f	
Chaetoceros curvisetum Cleve	f	f	f	f		f		f	f				f	f	f	f	f	f	f	f	f	f	f	f
Chaetoceros dadayi Pavillard					f	f						f					f							
Chaetoceros danicum Cleve						f	f	f	f	f	f	f	f									f	f	f
Chaetoceros decipiens Cleve	f				f	f	f	f	f	f	b	f					f	f	f	f	f	f	f	
Chaetoceros decipiens Cleve	f				f	f	f	f	f	f	b	f					f	f	f	f	f	f	f	
Chaetoceros didymum Ehrenberg	f								f			f	f	f	f		f					f	f	

Table 1 Continue

	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
Chaetoceros diversum Cleve	f				f	f	f					f												
Chaetoceros laciniosum Schütt	f	f				f	f	f	f					f				f						
Chaetoceros lauderi in Lauderi	f	f				f	f	f	f	f			f		f		f			f				
Chaetoceros cf. *lorenzianum* Grunow			f			f		f	f															
Chaetoceros peruvianum Brightwell	f				f	f	f	f	f	f	f	f	f	f					f	f				
Chaetoceros rostratum Lauder	f					f	f	f	f	f	f	f	f				f		f		f	f	f	
Chaetoceros saltans Cleve	f				f						b	f												
Chaetocerus sociale Lauder											b		f				f		f	f		f		
Chaetoceros tetrastichon Cleve																		f						
Chaetoceros cf. *teres* Cleve						f																		
Chaetoceros tortissimum Gran	f				f											f	f							
Chaetoceros cf. *vixvisibilis* Schiller									f				f						f					
Chaetoceros wighame Brightwell	f	f			f	f	f	f	f	f				f			f		f					
Chaetoceros sp.	f	f		f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f
Climecosphenia sp.		f				f																		
Coscinodiscus asteromophalus Ehrenberg		f				f	f	f	f		f		f	f	f	f	f	f	f	f	f	f	f	f
Coscinodiscus gigas Ehrenberg													f			f						f		
Coscinodiscus granii Gough						f			f							f				f	f	f	f	
Coscinodiscus janischi Schmidt	f					f		b					f			f	f							
Coscinodiscus jonesianus (Greville) Ostenfeld		f				f	f						f			f	f							
Coscinodiscus sp.	f	f	f			f	f		f						f	f	f	f	f	f	f		f	
Detonula confervacea (Cleve) Gran						f	f	b		f						f	f	f	f		f			
Ditylum brightwelli (West) Grunow in Van Heurck															f	f			f		f	f	f	
Eucampia cornuta (Cleve) Grunow in Van Heurck						f	f	f		f								f	f		f			
Eucampia zodiacus Ehrenberg																				f				
Grammatophora marina (Lyngbye) Kützing																								f
Guinardaia cylindrus (Cleve) Hasle					f																			
Guinardia flaccida (Castracane) H. Peragallo	f		f	f	f	f	f	b	b	f	b	f	f		f	f	f	f		f	f	f	f	f
Gyrosigma attenuatum Kützing) Robenhorst		f	f																					
Gyrosigma balticum (Ehrenberg) Hassal					f																			
Gyrosigma hippocampus Ehrenberg					f																			
Hemiaulus hauckii Grunow in Van Heurck	f	f	f	f	f	f	f	b	b	f	b	f	f		f	f	f	f	f	f	f	f	f	f
Hemiaulus sinensis Greville								f	f		f	f	f	f			f							
Leptocylindrus danicus Cleve		f	f	f	f	f	f	f	f	f	b	f	f				f	f	f	f	f	f	f	f
Leptocylindrus minimus Gran			f			f		f																
Lithodesmium cf. *undulatum* Ehrenberg							f	f																
Licmophora abbreviata Agardh				f			f	f	f	f										f				
Licmophora ehrenbergii (Kützing) Grunow																				f		f	f	f
Licmophora sp.		f			f				f	f	f	f	f		f	f	f	f		f	f	f		
Melosira moniliformis (Müller) Agardh	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f
Melosira nummoloides Agardh									f	f					f			f			f			
Melosira sulcata (Ehrenberg) Kützing	f	f	f		f				f			f	f	f		f				f		f		
Navicula cancellata Donkin													f											
Navicula sp.		f				f			f	f			f		f					f	f	f	f	
Cylindrothecha closterium (Ehrenberg) Reimann et Lewin	f	f	f	f	f	f	f	f	f	f	b	f	f	f	f	f	f	f	f	f	f	f		f

Table 1 Continue

	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
Pseudonitzschia delicatissima (P.T. Cleve) Heiden in Heiden et Kolbe		f					f	b		f	b	f			f	f	f	f	f	f	f	f	f	
Nitzschia longissima (Brebisson in Kützing) Ralfs in Pritchard	f	f	f	f	f	f		f		f			f		f	f								
Nitzschia seriata Cleve			f		f	f	f	b	b	b											f	f	f	
Nitzschia sp.	f	f	f		f		f	f	f	f			f	f	f	f	f	f	f	f			f	
Odontella aurita (Lyngbye) C.A. Agardh																			f					
Odontella mobiliensis (Bailey) Grunow	f	f	f	f	f	f	f	f	f	f	f		f		f	f	f	f	f	f	f	f		
Pleurosigma elongatum W. Smith							f		f	f	b					f	f	f		f	f	f		
Pleurosigma normani Ralfs in Pritchard			f	f					f		f	f	f		f	f				f				
Pleurosigma rigidum Wb Smith			f													f	f				f			
Pleurosigma sp.		f	f		f	f				f	f								f	f	f			
Rhabdonema adriaticum Kützing	f	f		f	f	f	f	f	f	f	f			f		f	f	f	f	f	f	f	f	
Rhizosolenia alata Brightwell	f	f	f	f	f	f	f	f	f	f	b	f	f	f	f	f	f		f	f	f	f	f	f
Rhizosolenia alata f. *indica* H. Peragallo																								f
Rhizosolenia calcar avis Schultze	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f		f		f		f	f
Rhizosolenia delicatula Cleve						f	f																	
Rhizosolenia hebetata Bailey																					f	f	f	
Rhizosolenia imbricata Brightwell				f																				
Rhizosolenia robusta Norman in Pritchard																f	f							
Rhizosolenia stolterfothi H. Peragallo					f	f	f	f	f	f	b		f			f	f		f	f	f	f	f	
Rhizosolenia styliformis Brightwell	f	f	f	f	f		f	f	b		b	f			f	f	f	f	f	f	f	f		
Sheshukovia cf. *kolbei* Kützing	f	f	f						f	f	f	f	f	f	f									
Skeletonema costatum (Greville) Cleve								f		f	b							f		f		f	f	
Staurosira sp.							f		f							f								
Stenopterobia stigmatella (Gregory) R. Ross	f				f							f	f		f	f	f	f	f	f	f			f
Streptotheca tamesis Shrubsole						f										f	f	f	f					
Striatella delicatula Kützing			f																					
Striatella unipunctata (Lyngbye) Agardth	f	f		f			f	f	f	f		f	f			f								
Surirella fastuosa Shrubsole																	f			f				
Surirella pandura Peragallo													f											
Suriralle striatula Turpin																	f							
Surirella sp.	f	f					f			f						f			f					
Tabellaria flocculosa (Roth) Kützing					f			f		f		f			f				f		f			
Thalassionema nitzschioides (Grunow) Mereschkowsky	f					f	f	f	f	b	f	f			f	f	f	f	f	f				
Thalassiophysa hyalina (Greville) Paddock et Sims		f	f	f	f	f	f	f	f	f	f	f	f		f	f	f	f	f	f	f		f	f
Thalassiosira sp.								f											f	f	f			
Thalassiothrix frauenfeldii Grunow	f	f	f	f	f	f	f	b	b	b	b	f	f	f	f	f	f	f	f	f	f	f	f	f
Thalassiothrix longissima Cleve et Grunow			f	f	f	f	f	s	f	f	f	f		f				f			f			
Thalassiothrix mediterranea Pavillard			f	f		f	f	b	b	b	b	f	f	f	f	f	f	f	f	f	f	f	f	
Unidentified-1		f	f	f						f		f	f	f	f	f	f	f		f	f	f	f	f
***EUGLENOPHYCEAE* (Euglenoids)**																								
Eureptia viridis Perty									s		s													
***CHLOROPHYCEAE* (Chlorophytes)**																								
Spirogyra cf. *fluviatilis* Hilse	f	f																						
Small flafellates								s	s	s	s													

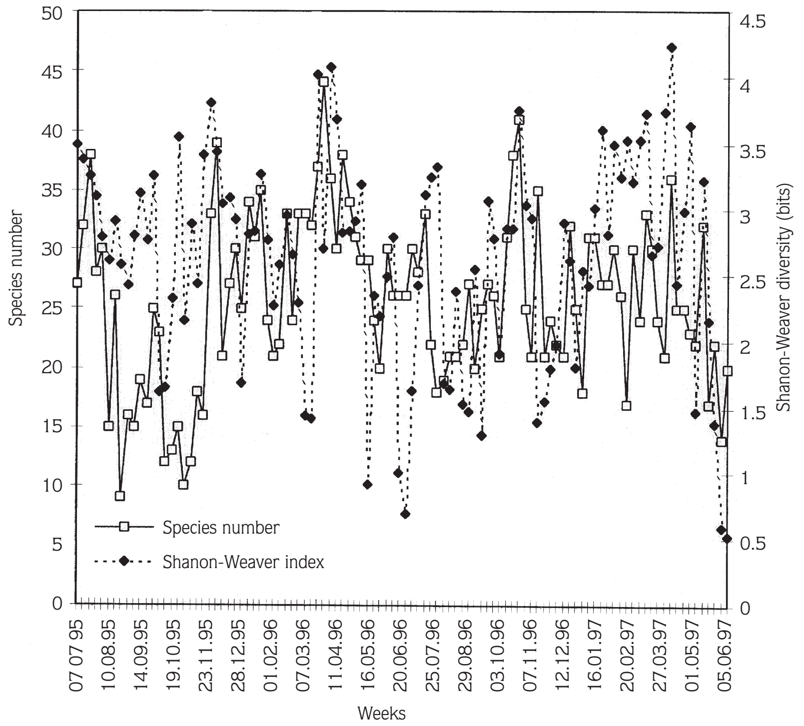

Figure 2. Variations in the Shannon-Weaver diversity indices and species number of phytoplankton in a harbour of Mersin Bay between 1995 and 1997.

Since the study period was longer and the sampling frequency was higher in the present investigation, the species number of phytoplankton was higher than in the above studies. However, it is worth noting that the effect of sedimentation on this species number was low; only 7 species out of 175 were observed in the filtered samples during the two-year sampling period. As in the other investigations, the species number of diatoms was usually higher than dinoflagellate numbers.

Maximum species diversity (4.48) was observed in April 1997, and the minimum (0.59) was calculated in June 1997 (Fig.2.) Kıdeyş et al. (6) found maximum (4.34) and minimum (2.16) diversities in June and February 1985, respectively. As can be seen, the range of diversity was greater and minimum/maximum values occurred in different months than in Kıdeyş et al. (6).

Temporal variations in phytoplankton abundance, composition and bloom timing

As in the number of species, the total abundance of diatoms in the filtered samples was significantly higher than that of dinoflagellates throughout the smapling period, similar to the findings of Kıdeyş et al. (6), Polat (19) and Carrada et al. (20). The diatom and dinoflagellate species displaying the highest average abundances during the two-year period are listed in Table 2.

In weekly samples, maximum total phytoplankton (>55 μm) abundances were detected on 8 February 1996 (11.7×10^3 cells 1^{-1} of which 5×10^3 cells 1^{-1} were comprised by the diatom *A. japonica*) and 19 June 1997 (11.1×10^3 cells 1^{-1} of which 10×10^3 cells 1^{-1} were comprised by the diatom *R. alata*). Minimum total phytoplankton and diatom abundances were found on 8 August 1996 and 26 October 1995.

Maximum dinoflagellate abundance (737 cells 1^{-1}) and maximum total phytoplankton species number (43 sp.) were determined at the same time, on 4 April 1996, in the filtered samples. In this sample, *P. micans, Pyrophacus horologium* Stein, *Protoperidinium oviforme* (Dangeard) Balech, *Ceratium fusus* (Ehrenberg) Dujardin, *Ceratium candelabrum* (Ehrenberg) Stein and *Gonyaulax turbynei* Murrey *and* Whitting were the dominant species. One day later a *P. micans* bloom (size range of 30-52 μm length and 20-24 μm diameter) was noticed in the sedimented samples. The colour of the sea was reddish brown. Numbers of this species incerased to 90.9×10^6 cells 1^{-1} on 5 April, while the previous day this concentration had been detected as 3.1×10^6 cells 1^{-1} in the sedimented samples, denoting a growth rate of 3.37 d^{-1}. Smayda (21) recorded the maximum daily growth rate of *P. micans* as 2.04 ± 0.10 d^{-1} in the culture media,

Diatoms	Concentration (cells 1^{-1})	Dinoflagellates	Concentration (cells 1^{-1})
Asterionella japonica Cleve et Müller	180	Prorocentrum micans Ehrenberg	5.1
Hemialus hauckii Grunow in Van Heurck	137	Protoperidinium depressum (Bailey) Balch	1.6
Rhizosolenia alata Brightwell	130	Pyrophacus horologium Stein	1.2
Thalassiothrix mediterranea Pavillard	128	*Ceratium fusus* (Ehrenberg) Dujardin	1.2
Thalassiothrix fraunfeldii Grunow	109	*Peridinium oviforme* (P. Dangeard) Balch	0.9
Pseudonitzschia delicatssima (P.T. Cleve) Heiden in Heiden and Kolbe	52.2	*Ceratium candelabrum* (Ehrenberg) Stein	0.8
Thalassionema nitzschioides Hustedt	48.1	*Pyrophacus steinii* (J. Schiller) Wall et Dale	0.7
Skeletonema costatum (Greville) Cleve	43.7	*Ceratium tripos* (O.F. Müller) Nitzsch	0.5
Chaetoceros decipiens Cleve	23.8	*Peridinium conicum* (Gran) Balch	0.4
Chaetoceros curvisetus Cleve	19.7	*Ceratium furca* (Ehrenberg) Claparede et lachmann	0.4
Chaetoceros compressum Lauder	18.8	*Gonyaulax sp.*	0.3
Bacillaria paradoxa Gmelin	10.4	*Ceratium trichoceros* (Ehrenberg) Kofoid	0.3
Bacteriastrum delicatulum Cleve Peragallo) Gran	9	*Ceratium massiliense* (Gourret)	0.3
Chaetoceros danicus Cleve	7.8	*Protoperidinium oceanicum* (Ehrenberg) Balch	0.2
Guinardia flaccida (Castracane) H. Peragallo	7.1	*Peridinium oceanicum* (Vanhöffen) Balch	0.2
Eucampia cornuta (Cleve) Grunow in Van Heurck	6.2	*Ceratium macroceros* (Ehrenberg) Vanhöffen	0.2

Table 2. Species displaying the highest average abundances between 7 July 1995 and 26 June 1997 in the filtered samples.

which is about 1.5 times less than in the field data of the present investigation.

On 9 May 1996, the dinoflagellate concentration was also high; the dominant species then were *Protoperidinium depressum* (Bailey) Balech, *Pyrophacus horologium* and *Peridinium oviforme.* Minimum dinoflagellate abundances were found in winter months, in Kıdeys et al. (6) between November 1984 and October 1985, the highest diatom ($6.60x10^3$ cells 1^{-1}) and dinoflagellate (6.7 cells 1^{-1}) cell numbers were found in February 1985 and centric diatoms (*Chaetoceros* Ehrenberg and *Rhizosolenia* Brightwell) were found to be abundant. Minimum abundance values were recorded in June and July 1985 (~2 cells 1^{-1}). Polat (19) also found that the abundance of diatoms was higher than that of dinoflagellates and, in general, the abundance of phytoplankton increased at the end of January and the middle of April in Iskenderun Bay between September 1994 and October 1995, similar to the findings in the present investigation. She found the maximum average abundance ($52.7x10^3 \pm 125x10^3$ cells 1^{-1}) in October 1995. This abundance value was approximately 10 times higher than the average of the other months. The reason for such a high abundance in this period was the diatom *Pseudonitzschia pungens* (Grunow ex P.T. Cleve) Hasle. The concentration of this species increased to $3.8x10^5$ cells 1^{-1} at station 5, which is located close to the Toros Fertilizer Factory. Blooming species in her investigation were *Cerataulina pelagica* (Cleve) Henley, *Guinardia flaccida* (Catracane) *H. Peragallo* and *P. pungens* (all are diatoms). Furthermore, the most common diatom species, in spite of their low concentrations, were *Thalasiothrix fraunfeldii* Grunow, *Hemiaulus hauckii* Grunow in Van Heurck, *Rhizosolenia calcar-avis* Schultzer, *Rhizosolenia stolterfothii* H. Peragallo, *R. alata, Chaetoceros decipiens* Cleve, *Chaetoceros affinis* Lauder and *Leptocylindrus danicus* Cleve. Widespread dinoflagellate species in her study were *Ceratium kofoidi* Jörgensen, *Ceratium tripos* (O.F. Müller) Nitzsch, *Ceratium fusus* (Ehrenberg) Dujardin, *Ceratium massiliense* (Gourret) Jörgensen, *Ceratium candelabrum* (Ehrenberg) Stein, *Ceratium contortum* Sourina, *Ceratium arietinum* Cleve, *Protoperidinium divergens* (Bailey) Balech, *P. micans* and *Dinophysis caudata* Saville-Kent. Similar to the present study, the dinoflagellate species that achieved high abundances ($6.4x10^3$ cells 1^{-1} at station 5, in May 1995) was *P. micans.* Supporting the studies of the other researchers, Carrada et al. (20) also noted that diatoms were the richest and most abundant phytoplankton component in the Gulf of Naples in the winter. They found the following species to be particularly abundant: *A. japonica* (which had the highest average abundance throughout the sampling period in the present study), *Lauderia borealis* Gran, *L. danicus, Nitzschia seriata* Cleve, *T. fraunfeldii,* several species of *Chaetoceros, Bacteriastrum* and *Rhizosolenia.* Furthermore, they recorded that these species had high reproduction rates, especially in turbulent and nutrient-rich waters, and represented the core phytoplankton of late winter at the onset of the seasonal cycle in the Mediterranean Sea (20).

In the present study, it was observed that diatoms reached maximum abundances in November, December, January, February or March (max: $11.7x10^3$ cells 1^{-1} in February) and dinoflagellates (max: 199 cells 1^{-1}) followed the same pattern in April or May (Fig. 3).

Stever(1935; in El-Maghraby and Halim) reported that two annual blooms of phytoplankton occurred in Alexandria waters in April and September respectively. Later, El-Maghraby & Halim (4) observed that the abundance of phytoplankton increased during January-February ($2.5x10^5$ cells 1^{-1}), and that with the discharge of nutrient-rich Nile flood waters, the standing crop exceeded the exceptional value of $9x10^6$ cells 1^{-1} in September 1957 before the construction of the Aswan High Dam on the River Nile in 1965. Kimor & Wood (5) found maximum phytoplankton abundance values to be $7.9x10^5$ cells 1^{-1} in the deep waters of the eastern Mediterranean Sea. They found the peak value near the Nile Delta to be $1.3x10^6$ cells 1^{-1} at 40 m.

The phytoplankton concentration in the Mediterranean Sea generally rises in February and April, but exceptional increases can also be observed in different months, as was the case in June 1997 in the present study.

Gottis-Skretas & Friligos (22) reported that a weak negative correlation exists between phytoplankton abundance and temperature in spite of the absence of correlation between abundance and nutrients (N, P, Si). They suggested the reason for such negative correlation (i.e., low phytoplankton abundance in high temperature) to be extensive grazing and inhibiting light intensities

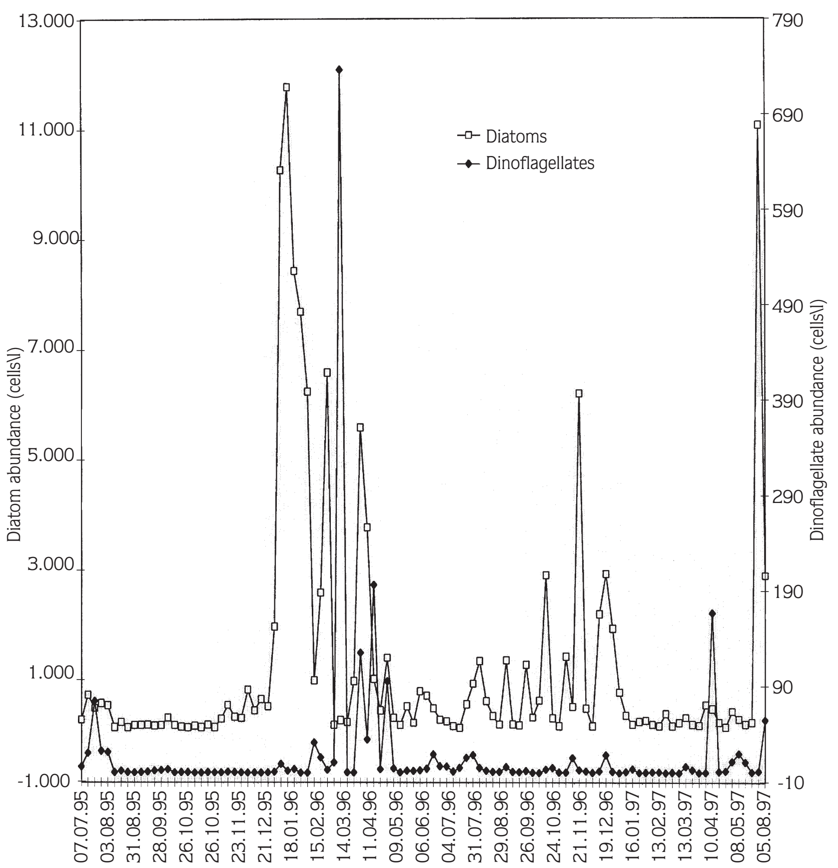

Figure 3. Diatom and dinoflagellate abundances in a harbour of Mersin Bay between July 1995 and June 1997 in the filtered samples.

during the summer period. In the present investigation, temperature correlated positively with dinoflagellate abundance (P=0.006, R=0.26), whereas it correlated negatively with diatom (P=0.01, R=-0.24) and total phytoplankton (P=0.009, R=-0.25) abundances. The positive correlation between dinoflagellate abundance and temperature can be explained by the adaptation of dinoflagellates to high temperatures. Therefore, dinoflagellates inhabit warmer parts of the world's oceans and are dominant in warmer seasons (23). In the present study, the lowest temperature (13°C) was measured in April 1997, while in 1996 the lowest temperature values were measured in January, February and March, at 14°C. The maximum seawater temperatures (29°C) were measured in August 1995 and 1996 (Fig. 4).

Kimor & Wood (5) recorded that the maximum phytoplankton abundance was usually observed at 80-120 m depth (below 1% light penetration) corresponding to the deep Chl-a maxima and at the same time to the nutricline (19) in the Meditteranean Sea. Robarts et al. (25) reported that in the Levantine Basin of the southeastern Meditteranean Sea, bacterial numbers ranged from 0.40 to 3.90×10^{8} cells 1^{-1} and were generally highest above 110 m in October and November 1991. Unfortunately, cyanobacteria, which is known as the most significant group in oligothrophic seas (24), was not counted in the present study. However, the contribution of small groups, mostly coccolithophorids and small flagellates (<20 µm), to the total phytoplankton abundance was assessed and found to be 37±21%.

In the comparison process of sedimented samples and filtered samples, a large gap was detected between the abundance and species numbed of phytoplankton (the comparison was made between 14 filtered and 14 sedimented samples obtained independently between 15 February and 25 May 1996). It was found that ~89% of the diatoms had passed through the 55 µm mesh filter. The loss of dinoflagellates as a result of filtration was even higher than that of diatoms (~99%). However, the species number of phytoplankton in the filtered samples (72 diatoms and 40 dinoflagellates) was higher than that of sedimented ones (23 diatoms and 16 dinoflagellates).

Whilst the sedimentation method gives a much better estimate of phytoplankton abundance, the filtration method is superior in some respects. It allows scanning of a much wider area as the volume of filtered seawater increases. The Mediterranean Sea displays the characteristics of oligotrophic waters and therefore is a region of high diversity and low abundance. In a study on

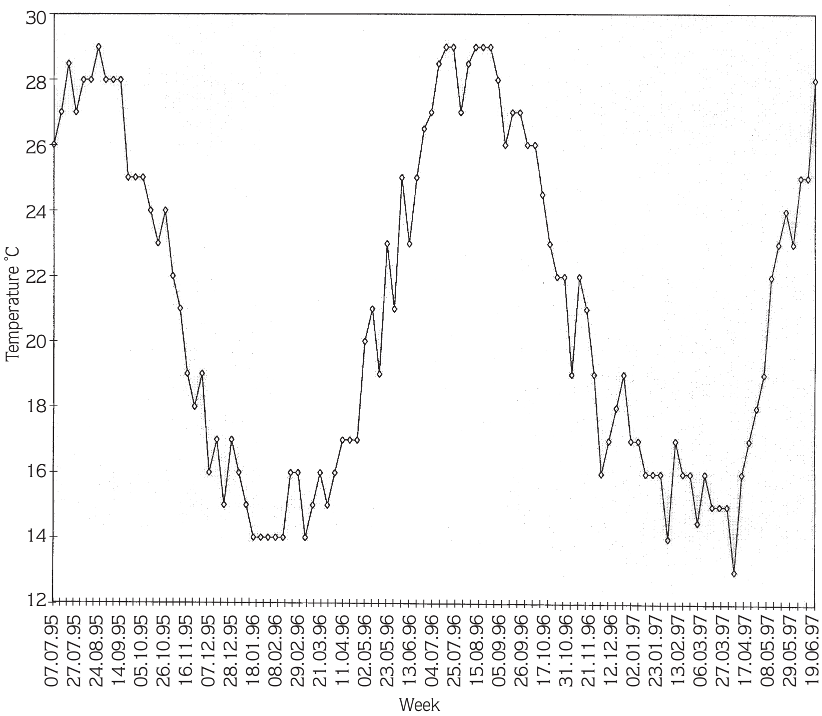

Figure 4. Weekly seawater temperature fluctuations in a harbour of Bersin Bay between July 1995 and June 1997.

species diversity, it is advisable to take a large seawater volume for sampling. Turner et al. (26) also suggested that 1-litre samples are not sufficient for the detection of species at low abundance, and they also used the filtration method in their studies in addition to gravimetrically settled 1-litre seawater samples. Furthermore, in the calculation of abundance with the sedimentation method, some rare cells (mostly large cells) may be overestimated or neglected since the volume of samples inspected is insufficient. It can be concluded that for the study of phytoplankton composition, where both species number and quantitiy are important, both methods should be used simultaneously.

So far, in most studies performed along the Turkish coasts, phytoplankton larger than 55 µm (by filtration technique) have been processed. During this study, it was revealed that a large amount of phytoplankton cells were lost with the filtration technique. However, the necessity of this technique was invetable in the assessment of species number.

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